Jan. 7, 1969 J. D. BIRD ETAL 3,420,471

JET SHOES

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FIG. 1a

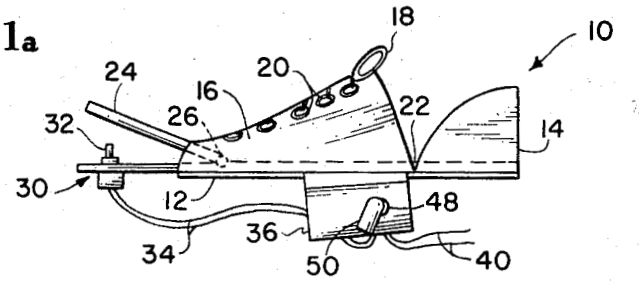


FIG. 1b

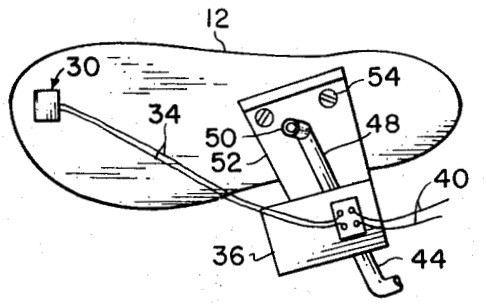
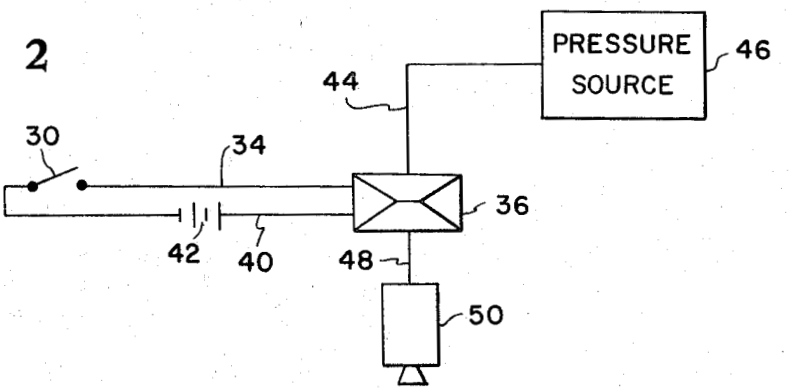


FIG. 2



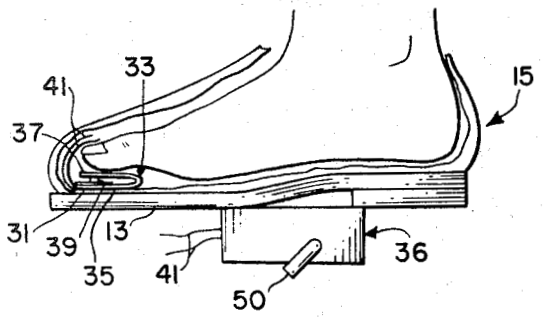


FIG. 3

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JET SHOES

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FIG. 4a

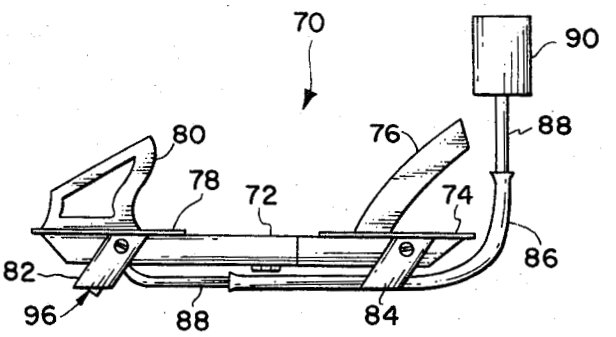
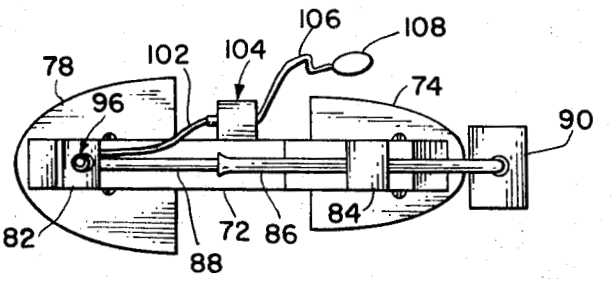


FIG. 4b



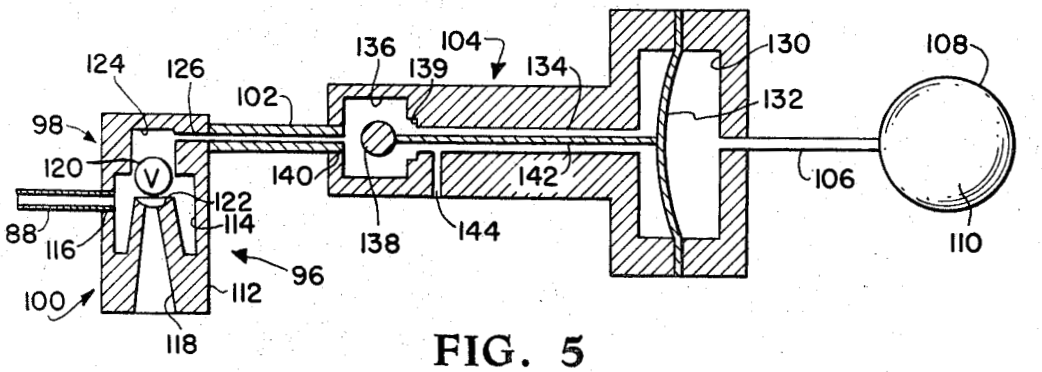


FIG. 5

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3,420,471

JET SHOES

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U.S. Cl. 244—4 11 Claims
Int. Cl. B64c 39/00; F03h 5/00; A43b 5/00

ABSTRACT OF THE DISCLOSURE

An apparatus for attachment to the feet of a person desiring extravehicular space locomotion having a fluid thruster controlled by the toes of the person. Toe end heel attachment elements are utilized for securing a base that supports the thruster and a control circuit therefor to each foot. The control circuit is either electric, having a switch for energizing a solenoid valve permitting fluid to flow through a nozzle, or fluidic, having a syringe connected to a relay that operates a valve permitting fluid to flow through the nozzle.

Specification

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without payment of royalties thereon or therefor.

This invention relates generally to apparatus for extravehicular space locomotion and more particularly to apparatus for attachment to the feet of a person desiring such locomotion.

Previous devices designed for extravehicular space locomotion include hand-held space gun, Manned Maneuvering Units ranging from a strap-on pack to a "shirt sleeve" operated taxi, tractors and physically jumping from one point to another. All of the jet powered devices known heretofore have had the disadvantages of either requiring the use of one or both hands during use or utilizing a complex arrangement of control jets and gyroscopic sensors or requiring both the use of the hands and a complex control system. The jumping technique requires the application of a high degree of skill and judgment in using a surface at the proper angle and velocity. There is no assurance that future astronauts will have suitable platforms from which to jump to possibly a very small target. Furthermore, none of these systems utilize the instinctive capability of man to control his path and at the same time leave his hands free for other tasks.

In view of the above noted disadvantages it is an object of this invention to provide a simple, instinctively or naturally controlled device for locomotion under zero gravity conditions.

Another object of the instant invention is to provide a locomotion device for attachment to the shoes of a person to permit movement without requiring the use of one or both hands.

A further object of the instant invention is to provide a shoe or shoe attachment that supports a thruster controlled by the wearer's toes to effect locomotion.

Still another object of this invention is to provide a shoe attachment supporting a thruster activated by either an electrical or fluidic control circuit operated by manipulation of the toes of the wearer.

Yet another object of this invention is to provide a shoe attachment having a plate member capable of being depressed by movement of the toes of the wearer that closes a switch to energize a solenoid valve and thereby permit pressurized fluid to flow through a nozzle and establish a force for locomotion of the wearer.

A still further object of the instant invention is to provide a shoe attachment wherein manipulation of a syringe controls a fluidic relay for operation of a valve permitting fluid flow through a nozzle to establish a force for locomotion of the wearer.

Generally, the foregoing and other objects are accomplished by attaching a thruster activated by either an electrical or fluidic control circuit operated by manipulation of the toes of the wearer. The electrical control circuit includes a depressible plate for closing a switch that energizes a solenoid valve to permit pressurized fluid to flow from a pressure source through the thruster nozzle. The fluidic control circuit has a syringe for compressing or expanding a fluid to operate a valve permitting pressurized fluid flow through the nozzle to effect a force for locomotion of the wearer.

A more complete appreciation of the invention and many of the attendant advantages thereof will be readily apparent as the same becomes better understood by reference to the following description when considered in connection with the accompanying drawings wherein:

FIG. 1 shows an embodiment of the instant invention in an elevation and bottom view;

FIG. 2 shows a diagrammatic sketch of the control circuit for the embodiment of FIG. 1;

FIG. 3 shows an alternative arrangement of a portion of the embodiment of the invention shown in FIGS. 1 and 2;

FIG. 4 shows an alternative embodiment of this invention in a side and bottom view similar to those of FIG. 1; and

FIG. 5 is a schematic diagram of the control circuit for the embodiment of the invention shown in FIG. 4.

Referring now to the drawings and more particularly to the embodiment of the invention shown in FIGS. 1 and 2 wherein jet shoes **10** are shown to include a base or longitudinal sole support **12** having heel attachment **14** and toe attachment **16**. Toe attachment **16** is similar to a normal shoe in construction and utilizes laces **18** through eyes **20** for securement of base **12** to the shoe of the subject. Inner sole **22** may extend substantially the length of base **12** or some portion thereof. Toe plate **24** is pivotal about hinge **26** in order to permit depression thereof by the toes of the person on whom shoe **10** has been attached. Switch **30** is of conventional construction and is mounted on base **12** in a position to permit toe plate **24** to operatively engage button **32**. That is, button **32** is maintained in a position such that switch **30** is open until button **32** is depressed against the spring or other internal mechanism for maintaining switch **30** open. Switch **30** is connected with solenoid valve **36** by electrical leads **34**. Leads **40** connect solenoid valve **46** with power source **42** and switch **30** to provide a closed electrical circuit.

A source of high pressure fluid **46** is connected by line or conduit **44** to solenoid valve **36** and conduit **48** connects valve **36** with nozzle or thruster **50** to provide a system for permitting fluid flow from high pressure source **46** through valve **36** and out nozzle **50** to establish a thrust or force against base **12** and the person to whom the jet shoes have been attached. Solenoid valve **36** and nozzle **50** are attached to plate **52** that in turn is secured to base **12** as by screws or bolts **54**.

It is readily apparent that in order to operate the instant invention in the vacuum environment of outer space, it is necessary to locate the switch in the boot of a space suit. FIGURE 3 shows switch **31** mounted on lower leg **35** of U-shaped member **33** made of a spring

metal. Upper leg **37** functions as plate **24**, FIGURE 1*a*, in that its depression by the toes of the wearer causes button **39** of switch **31** to close the electrical circuit and energize solenoid valve **36**. Member **33** is mounted on the inside of sole **13** of boot **15**. Leads **41** connect switch **31** to solenoid valve **36** and are led from the inside of boot **15** in any conventional manner permitting maintenance of space suit integrity. Solenoid valve **36** and nozzle **50** are mounted on the outside of sole **13** of boot **15** in a conventional manner.

Referring now to FIGS. 4 and 5 wherein an alternative embodiment of the instant invention is shown to include "jet shoes" **70** having a base or beam **72** that would extend longitudinally along the bottom of the shoes of the person desiring extravehicular space locomotion. Heel plate **74** and heel attachment **76** are secured to base **72** as are toe plates **78** and toe attachment **80**. Support or bracket **82** mounts thruster **96** on base **72** for a purpose to be described more fully hereinafter. Bracket **84** on base **72** supports protector **86** for protection of fluid line **88** which connects thruster **96** with fluid pressure source **90**.

Thruster **96** includes valve **98** and nozzle **100** which, as seen in FIG. 5, are connected by vent line **102** to relay **104**. Relay **104** is connected by a flexible tube or conduit **106** to thin metal syringe **108**. Syringe **108** and flexible tube **106** are filled with a fluid **110** as will be described more fully hereinafter.

Thruster **96** includes valve **98** and nozzle **100**. Casing **112** of thruster **96** has a larger inner chamber **114** connected to conduit **88** through aperture **116**. Nozzle **100** includes divergent exhaust cavity **118** having interior seat **122** for ball **120** of valve **98**. Smaller chamber **124** is of a dimension slightly larger than the diameter of ball **120** to permit ball **120** to be displaced by fluid pressure from line **88** in chamber **124**. Aperture **126** connects vent chamber **124** with vent line **102**.

Relay **104** includes a large basic chamber **130** divided by diaphragm **132** such that fluid **110** is permitted access only to a portion of chamber **130**, flexible tube **106** and syringe **108**. Bore **134** connects first chamber **130** with second chamber **136** which houses ball **138**. Rabbet **139** provides a seat for ball **138** to close bore **134** and aperture **140** permits communication of vent line **102** and chamber **136**. Rod **142** abuts diaphragm **132** and is moved thereby to control the positon of ball **138** in second chamber **136**. Vent **144** connects bore **134** with the surrounding atmosphere. It is to be understood that vent **144** could be located at any convenient position to connect either bore **134** or the nonfluid containing portion of chamber **130** with the surrounding atmosphere.

Operation

The embodiment of the instant invention shown in FIGS. 1 and 2 utilizes an electronic control circuit to activate the thruster. Depression of toe plate **24** by manipulation of the toes of the wearer closes switch **30** causing current to flow in leads **34**. Because the circuit to power source **42** is closed, solenoid valve **36**, which is of conventional construction, is energized and permits a pressurized fluid, such for example as nitrogen, to flow through lines **44** and **48** and, accordingly, through nozzle **50**. As the gas issues from nozzle **50** a thrust is produced which acts more or less perpendicular to the sole of the shoe. The direction at which sole or base **12** is presented can be controlled by movement of the foot, ankle, knee or leg of the person to whom the shoes are attached. Release of pressure on toe plate **24** opens switch **30** de-energizing solenoid valve **36** which closes to prevent the flow of gas through lines **44** and **48** and nozzle **50** and thereby ceases the thrust. The alternative embodiment of the invention shown in FIG. 3 operates in a similar manner. Depression of leg **37** closes switch **31** to energize solenoid valve **36**. The primary distinction between the embodiments shown in FIGS. 1 and 3 is the insurance of space suit integrity which requires that switch **31** be located in boot **15** and connected to solenoid valve **36** by leads **41** led from the suit in a conventional manner.

Translational motions are primarily in the head foremost direction. Some lateral and fore and aft motions do occur as the result of inducing rotational motions. These motions are quite small in relation to the primary motion and are easily controllable. The wearer or subject's control of his motion is quite natural and instinctive in nature such that a short period of familiarization with the mechanics of the device is sufficient for the wearer to perform simple maneuvers. Control of the direction of translation is accomplished by rotating the body so that the head is pointed toward the target as in swimming. Rotations are controlled by the natural ankle and leg motions associated with balancing the body in a standing position. Thus, the native sense of balance of the wearer permits easy use of the instant invention because of the inherent stability and natural mode of locomotion.

The embodiment of the instant invention shown in FIGS. 4 and 5 functions in a manner similar to that of the device shown in FIGS. 1 and 3 but utilizes pneumatic or hydraulic principles for operation. Thin metal syringe **108** may be located inside the user's shoe under the toes or could be mounted in the sole of an astronaut's boots. Syringe **108** is emptied of control fluid, air or hydraulic fluid, by squeezing it with the toes. Control fluid **110** is forced through flexible tube **106** into chamber **130** of relay **104**. As control fluid **110** enters relay **104** it causes movement of diaphragm **132** to effect longitudinal movement of rod **142**. Movement of rod **142** to the left, FIG. 5, forces ball **138** from rabbet **139** and thus opens vent **144** and permits release of pressure from small chamber **124** in thruster **96**. Fluid under pressure from source **90** enters chamber **114** through conduit **88** and forces ball **120** from seat **122** when small chamber **124** is vented through line **102** to chamber **136** and to the atmosphere through vent **144**. However, with the vent line closed, the pressurized fluid from source **90** acts on the side and top surfaces of ball **120** and thereby forces ball **120** onto seat **122** and effects a seal to prevent further thrust.

Opening vent line **102** opens ball valve **98** that controls the flow of pressurized fluid, such for example as nitrogen gas, through nozzle cavity **118**. Once open, the ball valve stays open as long as vent line **102** is open. Flow of the gas or fluid through nozzle **100** produces a thrust in the same manner as in the embodiment of FIG. 1. Expansion of syringe **108** withdraws control fluid **110** from relay **104** and the consequential closing of vent aperture **139** by ball **138**. The pressure of the fluid entering chambers **114** and **124** from conduit **88** flows around ball **120** and forces it onto seat **122** to stop the thrust. The action of the above two-control systems, either the electrical or pneumatic-hydraulic type, is so rapid that the thrust can be pulsed as rapidly as the subject can move his toes.

A wide range of variation in design of the jet shoes is possible utilizing various power sources for the thrusters, control arrangements, and mountings of the thruster on the shoes or astronaut's boots. As for the thrusters, a jet utilizing a cold gas, such as nitrogen, would be about as simple as possible. Peroxide, a hot gas, jets could also be used. Throttleable jets would also be quite attractive for use with the instant invention. The principal requirement for the thruster is that the particular piece of equipment at which the thrust is produced be sufficiently compact that it may be mounted on the foot of the users. Skin divers, for example, might use small air driven propellers a few inches in diameter and rotating in a plane parallel to the soles of their feet in place of the jets.

The control system for the jets may take a number of forms basically either electrical, pneumatic, or hydraulic. The actual motion used to utilize the flow might be simply bending the toes as presently mechanized, bending the

toes both downward and upward, depending upon which direction of rotation is desired for rotational control, or using inertia as in kicking the feet in swimming. The second method would seem to be the most natural and the third would appear to be the most easily learned.

The thruster may be rigidly attached to the shoe in which event it would be positioned and aligned to suit the preference of the user. The device could incorporate an adjustable mounting in which case the individual would reposition the jets to suit himself. The most flexible arrangement would be a swivel mounting by which the user could augment the control deflection of the jet that is presently available from knee and ankle motions. The combination of a swivel mounted jet with a control linkage to augment control deflections, a hydraulic control system, using toe motions both up and down and the throttleable jets would provide a highly flexible, easily controlled system for extravehicular space operations.

This invention has the advantage over previous devices designed for extravehicular motion in that it is simple in design and reliable in operation. It can be made with but one moving part. That would be the main valve used to put the system on operational status which is not to be confused with turning the thrusters on. Since the control is instinctive, no electronic or inertia sensors are required for stabilization. Only two jets are required, one for each foot, as opposed to as many as sixteen on the more complex units. In addition, a very large advantage accrues to the jet shoe concept as the result of the control function being accomplished by the feet, which leaves the hands free for other tasks.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a locomotion device the combination comprising:
- thrust means for creating a reaction force;
- mounting means for attaching said thruster means to the foot of a person;
- control means to modulate the thrust produced by said thrust means operable by movement of the foot of the person to which the thruster means is attached, whereby movement is obtained through forces applied to the foot and controlled by movements of the foot so that natural instinctive control may be had.

2. The locomotion device of claim **1** wherein said mounting means comprises:
- base means for securement to the foot of the person desiring locomotion; and
- support means for mounting said thruster means on said base; and
- wherein said thruster means includes a source of fluid pressure and means for directing flow of said fluid to create said reaction force.

3. The locomotion device of claim **2** wherein said control means comprises:
- an electric circuit including a resilient switch and power source;
- said switch mounted on said base means for operation by a plate upon movement of the toes of the person desiring locomotion;
- said thruster including solenoid valve means and nozzle means, whereby toe movement depresses said plate to operate said switch and thereby energize said solenoid valve to permit fluid to flow from said pressure source means through said thruster means creating a force for movement of the person desiring locomotion.

4. The locomotion device of claim **2** wherein said thruster includes nozzle means for directing fluid flow; and valve means for controlling the flow of fluid through said nozzle.

5. The locomotion device of claim **4** wherein said control means comprises:
- a syringe connected by a tube to relay means;
- said relay means connected to said thruster means, whereby operation of said thrust means is accomplished by expansion or counteraction of said syringe.

6. The locomotion device of claim **1** wherein said nozzle means is directed downward and forward with respect to said support means, whereby greater angular positioning is accomplished by ankle and knee movements of the person desiring locomotion.

7. The locomotion device of claim **5** wherein said nozzle and valve means are housed in a casing:
- said nozzle means comprising a large chamber connected with the small end of a divergent cavity;
- a conduit connecting said large chamber with said pressure source means;
- seat means at the small end of said cavity in said large chamber for receiving a ball to prevent fluid from flowing from said large chamber into said cavity;
- said valve means including a small chamber of less cross-sectional area than said large chamber;
- a vent tube connecting said small chamber with said relay means; and
- a ball of slightly less diameter than the cross-sectional dimension of said small chamber for closing the small end of said cavity.

8. The locomotion device of claim **5** wherein said relay means comprises:
- a first chamber divided by a diaphragm into two portions;
- one portion of said chamber connected with said tube connected to said syringe;
- a second chamber connected with the other portion of said first chamber by a bore;
- an aperture connecting said second chamber with a vent tube leading to said valve means;
- a rabbet at the junction of said bore and said second chamber;
- a rod disposed in said bore having one end in juxtaposition to said diaphragm and the other end extending into said rabbet;
- a ball in said second chamber in juxtaposition to said other end of said rod and said aperture; and
- a vent connecting said bore and the other portion of said first chamber with the atmosphere, whereby compression of fluid in said one portion of said first chamber effects movement of said diaphragm to push said rod against said ball and thereby open said vent permitting communicating of said second chamber with the atmosphere.

9. The locomotion device of claim **8** wherein said nozzle and valve means are housed in a casing:
- said nozzle means comprising a large chamber connected with the small end of a divergent cavity;
- a conduit connecting said large chamber with said pressure source means;
- seat means at the small end of said cavity of said large chamber for receiving a ball to prevent fluid from flowing from said large chamber into said cavity;
- said valve means including a small chamber of less cross-sectional area than said large chamber;
- a vent tube connecting said small chamber with said relay means; and
- a ball of slightly less diameter than the cross-sectional dimension of said small chamber for closing the small end of said cavity.

10. The device of claim **1** wherein forces created by said thruster means is directed downwardly from said person by said mounting means whereby the force applied by said thrust means is applied in a similar manner to gravitational forces.

11. The device of claim **10** wherein said control means is operable by the toes of the person to which the device is secured whereby instinctive flexing of said toes may be used to control said thruster means.

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280—11.11